

# MASTER OF SCIENCE IN MECHANICAL ENGINEERING

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## THE EFFECT OF STIFFENER SMEARING IN A SHIP-LIKE BOX STRUCTURE SUBJECTED TO AN UNDERWATER EXPLOSION

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Shock trials for naval vessels are a requirement for each new class of surface ships in the U.S. Navy. With understanding the technology of underwater shock analysis and considering the rising costs of conducting actual shock tests, computer simulation of shock trials is becoming more and more attractive. Unfortunately, finite element models can be quite large and require sufficient amounts of computer memory and time to run a shock analysis. This thesis investigates the effects of reducing the element size of a shiplike box model subject to an underwater explosion. Known as smearing, this process combines the density and stiffness properties of the removed elements into the remaining material of the model. Positive results from computer simulation could greatly affect the manner in which shock trials are conducted with future ship classes.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Underwater Explosion, Smearing, Surface Model

## AXIAL CONDUCTION EFFECTS IN LAMINAR DUCT FLOWS

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A numerical model for heat transfer in laminar duct flows has been developed using the finite difference method to explore the significance and extent of “back-conduction” at low Peclet numbers. The calculations have been carried out for flows between parallel plates and in circular tubes by using different Peclet numbers in the range of 0.05 to 100. For both situations constant heat flux and constant wall temperature boundary conditions were used. The validity of the results has been checked by comparison with some existing results in the literature, and extended to a wider range of parameters including conjugate wall conduction effects. The results are presented for bulk mean temperature variation, Nusselt number behavior, and energy absorbed before the heated section, for cases with and without wall conduction. Such axial conduction effects may be an important feature in the thermal characterization of microtubes, which are to be used in microheat exchangers.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Laminar Duct Flows, Convection and Conduction Heat Transfer, Axial Conduction, Micro-heat Exchangers

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### **A NUMERICAL STUDY OF HEAT TRANSFER BEHAVIOR IN WELDING**

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A numerical model has been developed for three-dimensional transient conduction based temperature calculations in underwater wet welding on a thick rectangular plate. The numerical scheme is based on a fully implicit finite volume method. A variable mesh size centered around the moving heat source, and temperature dependent thermal properties have been used in the calculations. Convective, radiative and boiling surface thermal conditions have also been included. The weld pool region itself has been modeled as a solid region of thermal conductivity higher than the surrounding unmelted region. The validity of the results was checked by comparison with Rosenthal's three-dimensional solution for a moving point heat source, and other results in the literature.

**DoD KEY TECHNOLOGY AREAS:** Materials, Processes, and Structures, Modeling and Simulation

**KEYWORDS:** Underwater Wet Welding, Heat Transfer, Finite-Volume Numerical Method

### **AIRCRAFT TRAILING VORTICES: GREENE'S MODEL VERSUS FIELD DATA**

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Trailing vortices shed from aircraft pose great danger to following aircraft. Too much separation time reduces the effective use of airports, while too little separation poses grave dangers. The accurate determination of the optimal separation time between two following aircraft in a landing corridor became a major international concern. The LIDAR data, obtained by the Lincoln/MIT laboratories at various airports, have been used to analyze in as much detail as possible the velocity, circulation, and the decay mechanisms of trailing vortices. The results have been used to assess the predictions of Greene's model for a number of cases towards the creation of a more reliable model for use in all types of environmental conditions.

**DoD KEY TECHNOLOGY AREA:** Air Vehicles

**KEYWORDS:** Vortex, Aircraft, Wake

### **TRANSIENT RESPONSE ANALYSIS OF THE 72 INCH TAC-4 RUGGEDIZED SHIPBOARD RACK SUBJECTED TO AN UNDERWATER EXPLOSION EVENT**

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The finite element modeling and subsequent transient analysis of the 72 Inch TAC-4 Rugged Rack computer system (configurations 000 1AA and 0003AA only), currently employed in U.S. Navy shipboard applications, has been performed to determine the system's response to simulated shock inputs. This rack is designed to allow incorporation of commercial-off-the-shelf (COTS) computer systems for naval tactical computing requirements while still meeting MJL-STD-901D, the applicable shock specification. By showing the viability of this computer simulation of the shock response of the current TAC-4 rack system, an argument for a lessening of the actual physical testing requirements for acceptance of future TAC systems can be made.

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**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Transient Analysis, Finite Element Method, TAC-4, COTS, Shock Analysis, UNDEX

### **HUMAN MALE AND FEMALE BIODYNAMIC RESPONSE TO UNDERWATER EXPLOSION EVENTS**

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Ship survivability is a complex issue. For a ship to remain a viable warfighting asset following damage resulting from enemy munitions such as mines or torpedoes, the ship's crew must remain sufficiently uninjured to be capable of employing the ship's weapons systems. Sophisticated computer simulations of human response, such as those made possible by the Articulated Total Body (ATB) Model, may be used to estimate injury potentials, and thus crew survivability, during underwater explosion events. With this goal in mind, accelerometer data and video footage recorded during live fire testing were used to generate and validate ATB models for both a seated and a standing Hybrid III Anthropomorphic Test Device (ATD). Subsequently, these models were used to estimate the biodynamic response and injury potentials for both male and female human subjects in a vessel subjected to underwater explosion events. This established a method for evaluating crew survivability for a given underwater explosion induced deck excitation.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Biodynamic Response, Underwater Explosion, Articulated Total Body Program

### **MICROCHEMICAL ANALYSIS OF NON-METALLIC INCLUSIONS IN C-MN STEEL SHIELDED METAL ARC WELDS BY ANALYTICAL TRANSMISSION ELECTRON MICROSCOPY**

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Microchemical analyses of the inclusions present in several shielded metal-arc steel weld metals were made by analytical transmission electron microscopy (TEM). Low alloy C-Mn steel weld metal samples were studied in which only the titanium and aluminum contents varied significantly. Carbon extraction replicas were made from each of the weldments and the inclusions were analyzed in the TEM by energy dispersive x-ray (EDX) and parallel electron energy loss spectroscopy (PEELS). The results indicated that, for weld metals containing small amounts of Al (13 ppm), the inclusions were comprised of MnO-SiO<sub>2</sub>, Tig (maybe as a compound) and Cu(Mn)S. As the Al content was increased to 160 ppm, Mn and Si no longer took part in the deoxidization process and the inclusion compositions were dominated by TiO and Al<sub>2</sub>O<sub>3</sub> along with some sulfides. For weld metal containing a much higher amount of Al (580 ppm) the inclusions became essentially mixtures of TiO, Al<sub>2</sub>O<sub>3</sub> and TiN sometimes complexed with sulfides. These inclusion chemistries were predicted by the use of equilibrium thermodynamics and their effect on the microstructure and mechanical properties of the steel weld metals investigated.

**DoD KEY TECHNOLOGY AREA:** Materials, Processes and Structures

**KEYWORDS:** Shielded Metal Arc Welding, C-Mn Steel Weldments, Non-Metallic Inclusions, Transmission Electron Microscopy

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